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Original Research

Preventive effect of yacon leaves capsule in reducing symptoms of Exercise-Induced Muscle Damage

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Significance for public health: Physical exercise is an activity to maintain health and fitness. However, Unaccustomed, strenuous high-intensity, or long-duration exercise will result in the risk of DOMS and inflammation. Nutritional intervention can be considered as a method to reduce the negative effect of unaccustomed, strenuous high-intensity, or long-duration exercise.

Abstract

Exercise-Induced Muscle Damage (EIMD) is the disruption of skeletal muscle after high-intensity exercise, leading to decreased performance. Furthermore, it is a common condition following vigorous exercise, particularly in individuals unaccustomed to performance. This disruption results in a decrease in strength, muscle soreness, swelling, and the release of several cytokines, both inflammatory and anti-inflammatory. Symptoms of EIMD include Delayed-Onset Muscle Soreness (DOMS) and a loss of physical function. Therefore, this study aimed to investigate the effect of a 14-day administration of yacon leaves capsule supplementation on DOMS and inflammation post-EIMD.

To achieve this, an experimental pretest and posttest control group design with a randomized control trial approach was adopted. A total of 32 Recreational male students of the Sports Science Universitas Negeri Surabaya were randomly and double-blindly assigned to either yacon capsule supplementation (n=16) or placebo (n=16) group. Participants were instructed to take a yacon capsule or placebo after breakfast for 14 days. The study groups were subjected to a muscle-damaging protocol consisting of 7 sets of 10 eccentric single-leg press repetitions on a leg press machine. DOMS and Interleukin 6 (IL-6) were determined at 0-h (baseline), 24-h, and 48-h post-exercise before and after 14-day supplementation periods.

The results showed that DOMS and IL-6 serum increased at 24 hours post-EIMD when compared to baseline. Additionally, a significant reduction in both DOMS and IL-6 serum levels was observed within the yacon group compared to the placebo group ($p < 0.05$).

In conclusion, yacon leaves capsule supplementation was able to attenuate the risk of muscle damage by decreasing DOMS levels and IL-6 serum in the blood.

Introduction

Recovery post high-intensity exercise is increasingly important as the sports and exercise become more competitive. After this exercise, muscle soreness, decreased energy, and decreased performance are observed. EIMD is the disruption of skeletal muscle that often occurs after such strenuous activities, potentially leading to decreased performance.¹ Furthermore, it is a common condition resulting from vigorous exercise, particularly among individuals unaccustomed to performance.² The disruption results in a decrease in strength, muscle soreness, swelling, and the release of several cytokines, both inflammatory and anti-inflammatory.³ According to several reports, EIMD frequently happens after intense and unfamiliar exercise, particularly when the activity includes a high intensity of eccentric contractions.^{1,4}

A prominent symptom of EIMD is DOMS, characterized by pain and tenderness which increases between 24 and 48 hours post-exercise⁵ and peaks from 24 to 72 hours, before gradually subsiding within 7 days.⁶ The mechanism of the symptom is not fully understood but is believed to be a result of microtrauma to muscle fibers. This trauma causes inflammation, leading to pain, swelling, and stiffness in the affected muscle.⁷ The severity of DOMS is influenced by factors such as the intensity and duration of exercise, the type of exercise, and individual differences in muscle adaptability, specifically when there is a focus on eccentric contractions.⁸ Despite not being classified as a disease or disorder, the symptom can induce discomfort and concern among athletes, due to the ability to impede participation in subsequent workouts.⁹ Furthermore, DOMS can cause discomfort and can limit the ability of athletes to perform or train optimally. The soreness and stiffness can limit the range of motion, causing difficulty in executing proper technique and form.^{10,11}

The precise mechanisms responsible for EIMD have not been extensively described. However, previous studies have shown that delayed-onset muscle damage is primarily caused by mechanical stress, particularly eccentric muscle contractions. Intense eccentric exercise lead to greater

microtrauma within muscle fibers and affects the cell membrane,^{11,12} thereby facilitating inflammatory response.¹³

Several studies focused on efforts to mitigate the risk of DOMS and muscle damage through the use of antioxidant supplements^{14,15} and other potential agents,^{16,17} yielding various results. Therefore, further investigations are required to explore additional approaches aimed at reducing the risk of DOMS and inflammation. The inclusion of alternative nutritional interventions as preventive ingredients is essential imperative. This study aimed to investigate effect of 14-day yacon leaves capsule supplementation on DOMS and inflammation post-EIMD.

Materials and Methods

Participants

A total of 32 healthy recreational males from the Sports Science Department of Universitas Negeri Surabaya were recruited to participate in this study. All the Participants had met the inclusion criteria of normal Body Mass Index and non-smoker. The exclusion criteria include drug treatment, consumption of chemical drugs, and any supplements. The participants were weight-matched and randomly assigned into Yacon (YG, n=16) and the placebo (PL, n=16) groups. During the study period, there was refrainment from strenuous activities or resistance training for a minimum of two weeks before exercise session. Additionally, the participants were not consuming any supplements or subjected to recovery strategies such as massage, stretching, or cryotherapy. Instruction to maintain the usual daily schedule during the experiment was provided. The participants were free from any pain or injury as assigned by the Physical Activity Readiness Questionnaire (PAR-Q) pre-exercise participation screening. Finally, informed consent was obtained and a low risk of bias was observed.

Experimental Design

The method used was a randomized double-blind placebo-controlled experiment design with randomized control trial approach. This design was developed as a step to investigate effectiveness of yacon leaves capsule supplementation for 14 days against DOMS and IL-6 as markers of inflammation following EIMD. The study was conducted for a month, commencing with an initial evaluation on day one to assess the state of the participants. Throughout the entire process, all participants were forbidden from partaking in any kind of exercise or intense physical activity for 30 days, with only the experimental exercise being permitted.

During the screening visit, participants completed a physical fitness capacity questionnaire which included information on weekly running frequency and volume, history of injuries and illnesses, and medication used in the 2 weeks before the start of the study. On the first visit, both YG and PL groups provided baseline data, including body weight, height, fat percentage, physical activity levels, and VO2 max, ensuring similar characteristics. Informed consent was obtained from all participants after receiving a thorough explanation of the study during this visit. During the second visit, which occurred 14 days after the supplementation period, a damaging exercise was conducted in order to induce effect of EIMD.

Both groups (YG and PL) were subjected to muscle-damaging protocol consisting of 7 sets of 10 eccentric single-leg press repetitions on a leg press machine.¹⁸ Exercise protocol session starts with a 10-minute warm-up comprising jogging. Previous study¹⁹ have showed that this specific protocol of EIMD elicits a sensation of pain (known as DOMS) in the quadriceps muscle of exercised leg. DOMS and Il-6 (Inflammation marker) were obtained 0-hr (1st visit), 24-h (3rd visit), and 48-h (4th visit) post EIMD (2nd visit). Participants were instructed to refrain from all physical activity and avoid taking anti-inflammatory drugs, treatments, and additional dietary supplements during the 30 days. A summary of the study design is presented in Figure 1.

Supplementation

YG received 500mg Yacon capsule per day, while the PL received placebo capsule containing 100 mg of corn starch. The participants orally consumed one yacon or placebo capsule per day with breakfast for 14 Days. Instructions were provided to refrain from anti-inflammatory drugs, treatments, and additional dietary supplements during the study. The participants were prohibited from engaging in exercise or strenuous physical activity for 30 days

Pain Score (DOMS) and IL-6 Assessment

The level of pain experienced from DOMS was evaluated using a visual analog scale (VAS) comprising 100 mm.^{6,11,20} The VAS score ranged from 0 mm (representing no pain) to 100 mm (showing the maximum level of pain that could be tolerated) and was specifically focused on the quadriceps muscle of the leg subjected to eccentric exercise. This assessment was conducted at 24-h and 48-h post the single-leg press test protocol. Additionally, VAS is a method for evaluating pain caused by acute exercise.

A total of 5 cc blood samples were obtained from the cubital vein and treated with EDTA to describe plasma levels of IL-6. The centrifugation process was performed at 3000 rpm for 15 minutes after the serum was stored in a freezer at a temperature of 20 °C until analyzed. Serum IL-6 was counted using commercially available Enzyme-linked immunosorbent assay (ELISA) kits according to the manufacturer's instructions. IL-6 levels were measured at 0-hr (Vaseline), 24-h (3rd visit), and 48-h (4th visit) post-EIMD. Assessment of the serum was conducted at the Institute of Tropic Disease and International Research Center Laboratory, Universitas Airlangga Indonesia to obtain CK Plasma data.

Statistical analysis

The data collected was processed manually and digitally to convert into significant information. The samples were assessed for normal distribution using the Kolmogorov-Smirnov method, and the result was positive ($p > 0.05$). Subsequently, descriptive statistics were calculated for

each measured variable. The paired sample t-test was adopted for analysis since the data was normally distributed.

Results and Discussion

A total of 32 male recreational students from the Sports Sciences Department of Universitas Negeri Surabaya, with a mean age of 19.47 (± 0.92) and 22.96 mean BMI (± 1.80) were included in the study. The participants were randomly assigned to YG and PL, with the mean ages being 19.44 (± 0.96) and 19.5 (SD ± 0.89), respectively. The variation in age, height, weight, BMI, Fat Percentage, IPAQ, and VO2 max is presented in Table 1. As shown in Table 1, the p values of all variables including age, height, weight, BMI, fat percentage, IPAQ, and VO2Max were >0.05 . This implied that both YG and PL were homogeneous groups.

The normality test was conducted to determine whether data of the VAS and IL-6 serum post 14-d of Yacon capsules supplementation period followed a normal distribution. The Kolmogorov-Smirnov was selected as the normality test to assess the distribution of the data. Table 2 shows details of the results obtained. Demographics of normality test results are presented in Table 2. Kolmogorov-Smirnov test was conducted to determine the normality distribution of VAS (pain score of DOMS) and IL-6 serum 0-h, at 24-h and 48-h. The result showed a p-value of >0.05 , indicating a normal distribution. Given the normal distribution of both the YG and PL data, the subsequent step comprised conducting a hypothesis test using a paired t-test. The objective of the test was to ascertain whether there was a reduction in DOMS (VAS) and IL-6 serum levels following 14 days of Yacon Capsules Supplementation.

Pain assessment

DOMS is a condition characterized by muscle pain that occurs in the days following intense or unaccustomed eccentric exercise, often accompanied by muscle damage resulting from repeated

contractions. In this study, the pain scores in the quadriceps were assessed using the VAS from baseline, at 24-h to 48-h post-EIMD, as shown in Table 3. The result showed that pain score using VAS showed a rise 24 hours post-exercise, followed by a decline 48 hours post-exercise in both YG and PL.

Figure 2 shows that there was an increase and decrease in the pain scores of both groups 24 and 48 hours after exercise, respectively. However, the reduction in pain score in YG between 24 and 48 hours was observed to be more significant compared to the PL group. Therefore, it was inferred that the supplementation of Yacon capsules led to a greater reduction in DOMS compared to the placebo.

Inflammation Assessment

Interleukin-6 (IL-6) is commonly used as a marker of muscle inflammation following heavy or uncustomed eccentric exercise. The result of comparative analysis of IL-6 serum level changes post 14-d of Yacon capsules supplementation, between baseline, as well as 24-h to 48-h post the single-leg press test protocol. Table 5 shows a significant increase between baseline and 24-h after exercise ($p < 0.05$) in both groups (YG and PL), which then decreased significantly ($p < 0.05$) after 48-h post the single-leg press test protocol. Furthermore, a significant decrease was observed between 24-h and 48-h post the single-leg press test protocol ($p < 0.05$) in both groups (YG and PL). Figure 3 shows a decrease in IL-6 levels between 24-h and 48-h in both groups ($p < 0.05$), but the reduction was greater in PL ($p < 0.05$). Therefore, the supplementation of Yacon capsules led to a greater reduction in DOMS compared to the placebo.

An intense physical activity without proper conditioning can result in damage to active muscle fibers. This damage is manifested through indications such as muscle soreness, stiffness (which can restrict the range of motion), and a decline in the capacity of muscle to produce force.^{3,21}

DOMS symptoms are commonly experienced by both elite and novice athletes which are particularly associated with uncustomed eccentric exercise.^{11,22} Furthermore, symptoms are often

accompanied by pain attributed to rapid muscle tissue damage.^{23,24} It is widely recognized that eccentric exercise leads to significant damage to muscle cells, thereby triggering an inflammatory response^{25–28}. Eccentric exercise such as post-single-leg press induces greater muscle damage than other types of muscle action due to micro-injury event.²⁹ This condition is hypothesized to occur when muscle stretch while contracting simultaneously, increasing stress on the myofibrils and disrupting the Z-disks.³⁰

Different mechanisms have been proposed to describe the pain sensation in DOMS, with one suggesting the overproduction of reactive oxygen species (ROS).^{31,32} However, no single theory can be identified as the primary factor accountable for these symptoms. Several theories stated that ROS due to increased oxidative stress during exercise was responsible for DOMS and muscle damage.^{14,33} Therefore, several studies advocate for treatment through nutritional interventions to reduce increased oxidative stress.

Yacon (*smallanthus sonchifolius*) leaves considered to an antioxidant and immune functions, contain phenolic compounds such as organic acids, flavonoids, and sesquiterpene lactones, which have various pharmacological effects.^{34,35} These leaves act as antioxidants by directly binding radical reactive groups and inhibiting the formation of enzymes that generate radicals.³⁶

Numerous studies have confirmed the effectiveness of yacon leaves supplementation as an antioxidant.³⁷ The capacity to reduce DOMS and muscle damage can be restricted, particularly during heavy eccentric exercise. Therefore, it is crucial to explore alternative and effective nutritional strategies. The present study examined the efficacy of a 14-day daily supplementation of yacon leaves capsules in relation to subjective indicators of DOMS and inflammation, promoting muscle recovery following intense eccentric exercise.

The results showed that a 14-day supplementation of yacon leaves capsules has an effect on eccentric EIMD, characterized by DOMS and IL-6 as inflammation markers, compared to placebo. This is evidenced by the mean difference between baseline, 24-h, and 48-h post-heavy eccentric exercise. Several mechanisms could potentially explain the beneficial effects observed in this study as

a result of yacon leaves capsule consumption. However, the most likely explanations are linked to the antioxidant capacity of yacon leaves. It is important to note that the relationship between antioxidant supplementation and exercise is still not fully understood. Additionally, vitamin C supplementation, which acts as an antioxidant, has been discovered to reduce the development of endurance capacity.³⁸ Studies showed that antioxidant supplementation may counteract the positive effect of exercise on insulin resistance.

Engaging in repetitive eccentric exercise leads to an elevation in oxygen consumption and mitochondrial activity, increasing the generation of ROS.³⁹ The advantage of ROS production during exercise lies in its role as signaling molecules that govern crucial molecular processes entailed in the adaptation of muscle cells to physical activity.^{40,41} Therefore, excessive production has detrimental effect, and when not balanced by the endogenous antioxidant system, oxidative stress can occur.⁴² To attenuate the harmful effects of ROS, antioxidants should be often consumed by highly active individuals such as athletes and hard workers to minimize muscle damage and alleviate symptoms of fatigue.^{43,44}

The exact mechanism of the DOMS remains unclear,^{45,46} but the reduction is attributed to the ability of yacon leaves capsule supplementation to decrease inflammatory response during the recovery phase following eccentric exercise. In this case, leaves can inactivate nuclear factor kappa B (NF- κ B), a major mediator of inflammation, thereby reducing the levels of other inflammatory mediators including pro-inflammatory cytokine mRNA and protein.⁴⁷ Additionally, other studies showed the supplementation significantly decreased IL-6 levels.⁴⁸

Despite the decrease in DOMS and IL-6 levels due to the administration of yacon leaves, it is important to acknowledge the potential of the antioxidant to impede muscle tissue recovery. This is because the majority of ROS production following eccentric exercise is highly attributed to phagocyte activity, which plays a role in tissue degeneration and subsequent regeneration. Furthermore,

antioxidant therapy could dampen such activity, thereby prolonging the recovery process. Further investigation in this field is necessary to substantiate the hypothesis.

Conclusions

In conclusion, the results of the current study showed that consuming yacon leaves capsules for 14 days was beneficial for reducing DOMS and muscle damage post-EIMD. Further investigation with various concentrations of leaves capsule was needed to assess the optimum dose and recovery duration. Finally, focus was given to the main indices that correlated with post-exercise recovery, consisting of the DOMS and the IL-6 levels.

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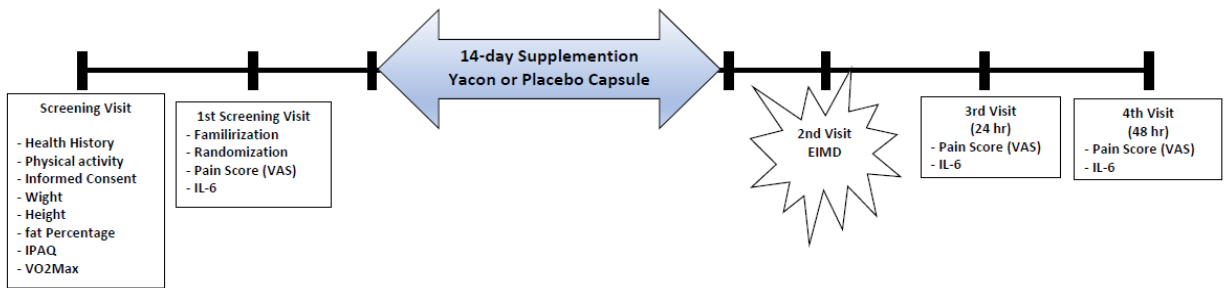


Figure 1. Study Design

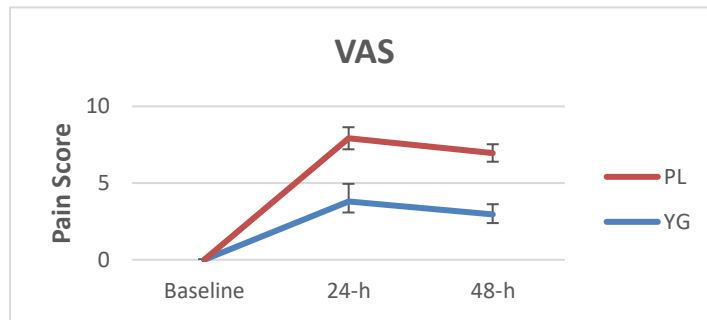


Figure 2. Changes in pain score levels between Baseline, 24-h, and 48-h post the single-leg press test protocol in both YG and PL

Table 1. Characteristic of Respondents

Categories	YG Mean (\pmSD)	PLA Mean (\pmSD)	P Values
Age (years)	19.43 (\pm 0.96)	19.5 (\pm 0.89)	0.128
Height (cm)	168.81 (\pm 4.65)	170.03 (\pm 4.84)	0.168
Weight (kg)	61.5 (\pm 3.03)	61.5 (\pm 3.46)	0.688
BMI	23.44 (\pm 1.53)	22.47 (\pm 4.84)	0.856
Fat Percentage (%)	22.43 (\pm 4.68)	21.25 (\pm 4.23)	0.544
IPAQ (MET)	1274.63 (\pm 215.26)	1184.67 (\pm 135.20)	0.442
VO2Max (mL/(kg·min))	39.21 (\pm 3.23)	38.50 (\pm 4.36)	0.667

Table 3. Pain score post-EIMD

Groups	Baseline Mean (\pmSD)	24-h Mean (\pmSD)	48-h Mean (\pmSD)	<i>P</i> Values
YG	-	3.83 (\pm 1.15)	2.96 (\pm 0.66)	0.000
PL	-	4.12 (\pm 0.72)	4.06 (\pm 0.57)	0.000